Wavelength-independent bent-fiber coupler to an ultra-high Q cavity demonstrated over 850 nm span

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Abstract: A bent tapered-fiber coupler is experimentally demonstrated to allow wavelength independent fiber-to-cavity coupling over an 850nm span; opening current technology of ultra-high Q cavities for applications spanning the UV to the IR band.
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Cavities possessing ultra-high quality-factor (Q) [1,2] were until now mainly investigated in the IR band. It is important that new coupling techniques are found to enable this ultra-high resonance enhancement in the full transmission range of silica from 250 to 2000*nm*. A new coupling technique using a centrifugal bent tapered fiber is experimentally demonstrated here for wavelength-independent coupling from an optical fiber to an on-chip optical micro-cavity with ultra-high Q. This constitutes the first time that an ultra-high Q cavity is fiber coupled over a wide spectral range. Usually, a coupler designed for one wavelength fails to couple at another due to phase mismatch, and using two couplers will result in undesirable scattering of one wavelength by the coupler designed for the other. To solve such problems we made an alternative coupler in the form of a bent-taper having the same geometry (fig. 1a) of the toroidal micro-cavity so that wavelength-independent phase match is automatically accomplished. The mode velocity responsible for the phase match is set by the rate of the centrifugal evanescent extension of the optical mode into the air, which is identical on both sides of the symmetrical coupling region. Moreover, for a given velocity mismatch, the bent geometry will be better phase-matched compared with a straight geometry thanks to the shorter interaction region. Indeed, we measured the bent coupler to allow efficient coupling over 850nm span. Specifically, the bent coupler is measured to couple 682nm visible light to a mode with Q of 23 million (fig 1b); tuning to a wavelength more than twice longer the coupling is still proper as evident by coupling to a mode with a Q of 24 million measured at 1540nm (fig 1c). The experiment was also repeated using a straight tapered-fiber coupler [3] designed for the IR. As expected, this reference straight couple functioned properly in the IR but allowed no coupling at all for the visible resonance due to the phase mismatch.

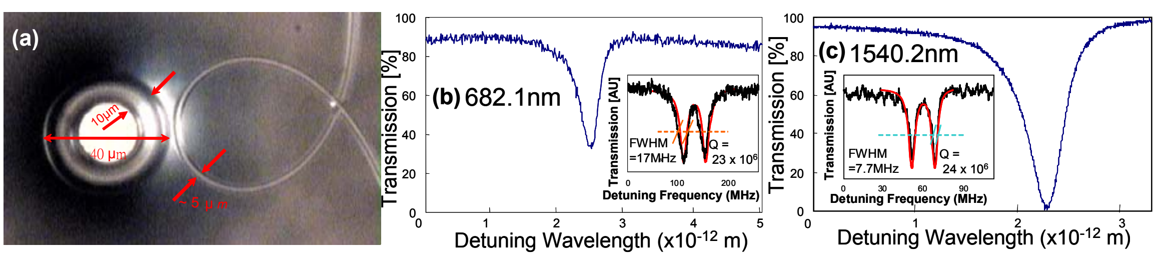

Fig 1. a. Bent taper coupler and micro-toroid resonator. b. Transmission spectrum in the visible. c. Transmission spectrum in the IR. Insets, under-coupled transmission is also measured to allow Q measurement with no thermal broadening. In these spectra, back-scatter-split doublets are apparent.

It is important to note that the bend here is only tens of microns in diameter and functioning to allow wavelength-independent coupling. This is in contrast with previous work (e.g. reference 4) in which a mm-scale bend provided a geometrical function of allowing access to flat cavities (but had no optical purpose). From the point of view of mechanical strength, the cross section of the bent fiber is more than one order of magnitude larger than a typical tapered fiber coupler, which implies proportionally better mechanical stability and heat dissipation at high power.

In conclusion, a mechanically robust, wavelength-independent fiber coupler is experimentally demonstrated over an 850 nm span. This new bent-coupler technology opens a regime of operation for coupling to high-Q microcavities in a wavelength range spanning from the UV to the IR. In addition to the considerable importance of wavelength-independent operation, the bent-coupler also has a higher mechanical strength.

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